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Mission Highlights STS-78

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Life sciences dominates longest shuttle flight to date

As Space Shuttle *Columbia* descended from the morning sky on to the runway at Kennedy Space Center, it brought to an end the longest shuttle flight to date. Commander Tom Henricks, Pilot Kevin Kregel, Mission Specialists Susan Helms, Rich Linnehan and Chuck Brady and Payload Specialists Jean-Jacques Favier and Bob Thirsk returned to Earth with a record 16-day, 21-hour and 48-minute flight.

The marathon mission was designed to determine the effects of long-duration space flight on humans and materials. It concentrated on long duration experiments and made extensive use of the Spacehab module.

In addition to the life sciences experiments, the STS-78 crew tested the Voice Command System that allows space travelers to command the onboard television system while performing other tasks. They also participated in a video conference with Mission Control. This system could ultimately provide two-way communication for the International Space Station (ISS).

"What we have shown in the last 17 days is something that you're going to see in the future on the space station as well," said Thirsk, "When you put together dedicated scientists, an enthusiastic crew, ingenious engineers, NASA resolve and international cooperation, you've got a formula for success."

Mission Events

The Space Shuttle *Columbia* blasted off from Florida's Kennedy Space Center on June 20, 1996 at 9:49 a.m. CDT. The STS-78 crew immediately

Payload Specialist Robert Thirsk performs a test on his arm using the Torque Velocity Dynamometer. In this view, Thirsk is measuring changes in muscle forces of the biceps and triceps.

Space Shuttle *Columbia*

June 20-July 7, 1996

Commander:	Terence T. (Tom) Henricks
Pilot:	Kevin R. Kregel
Mission Specialists:	Susan J. Helms Richard M. Linnehan Charles E. Brady, Jr.
Payload Specialists:	Jean-Jacques Favier Robert B. Thirsk

Astronauts Susan Helms and Tom Henricks prepare a sample cartridge containing semiconductor crystals for Spacehab research.

activated the Spacelab module which housed more than 40 life science and microgravity experiments in the shuttle's cargo bay.

For the next 16 days, the crew worked in the Spacelab module with experiments which included the Bubble Drop Facility, human behavior assessment and neurological and cardiovascular experiments.

On June 22, Astronauts Henricks and Kregel tested a device designed to permit voice control of the shuttle closed circuit television system. This allows astronauts to command the system verbally while performing other tasks.

Other experiments activated aboard *Columbia* included the Torque Velocity Dynamometer, Astronaut Lung Function Experiment and the bicycle ergometer and its associated instruments.

On June 27, work concentrated on sessions at the Human Behavior Workstation, which measured the ability of the astronaut to respond to changes in the environment. The crew also conducted investigations with the Astronaut Lung Function Experiment to measure the effects of microgravity and heavy exercise on pulmonary capability, and the Torque Velocity Dynamometer, which measures leg muscle strength.

By July 2, Spacelab studies had turned to muscle strength and energy expenditure, and astronaut pulmonary function. Processing of advanced semiconductor materials and alloys in the Advanced Gradient Heating Facility also proceeded uninterrupted.

Mission Specialists Linnehan and Brady, and Payload Specialists Favier and Thirsk participated in an integrated 72-hour study of sleep cycles, circadian rhythms and crew performance. Investigators monitored crew alertness and mood through a series of questionnaires. The astronauts also donned instrumented sleeping caps that monitored the quality of crew sleep.

The Space Shuttle *Columbia* wrapped up the record setting flight with a Kennedy Space Center Landing at 7:37 a.m. CDT on July 7, 1996.

Payload Descriptions

This is a partial list of the many scientific experiments that were conducted in the Spacelab module on STS-78.

Effects of Weightlessness on Human Single Muscle Fiber Function: Although the skeletal muscles continue to control and move the body when on orbit, astronauts experience muscle wasting similar to the aging process or inactivity. During crew sessions on an exercise ergometer, breathing and heart-rate measurements were made. Right calf muscle performance was evaluated using the Torque Velocity Dynamometer workstation. The experiment was sponsored by Marquette University, Milwaukee, WI.

Relationship of Long-term Electromyographic Activity and Hormonal Function to Muscle Atrophy and Performance: Researchers wanted to know whether unstressed muscles and the nervous system compensate for changes due to lack of adaptation and atrophy and restore movement ability both on Earth and in microgravity. Right arm and leg muscle movement were measured by the Torque Velocity Dynamometer and electromyograph electrical impulses. Subjects also compressed a Hand-Grip Dynamometer to measure hand strength. The experiment was sponsored by the University of California/Los Angeles, Los Angeles, CA.

Effects of Microgravity on Skeletal Muscle Contractile Properties: On Earth, we take muscle contraction for granted. In space, without gravitational resistance, muscle function is impaired. This investigation identified the effects of selective fiber atrophy, or shrinking. Muscles are made of fibers. The Percutaneous Electrical Muscle Stimulation device stimulates muscle contractions, enabling the Torque Velocity Dynamometer equipment to measure physical capabilities of these muscle types. The experiment was sponsored by Central Medical University, Geneva, Switzerland.

Effects of Microgravity on the Biomechanical and Bioenergetic Characteristics of Human Skeletal Muscle: Studies have shown that the maximum velocity at which a muscle can contract is inversely related to applied load, or resistance. Investigators wanted to know whether, and to what extent, this inverse relationship changes in microgravity. Using the Torque Velocity Dynamometer, crew members exerted a series of short elbow and ankle contractions made at different joint angles. The experiment was sponsored by the University of Udine, Italy.

Magnetic Resonance Imaging After Exposure to Microgravity (Ground Study): Many changes have been found in bone, muscle and blood from humans and animals exposed to microgravity. For example, astronauts often experience varying degrees of back pain, possibly related to lengthening of the spine in microgravity. These changes must be understood before longer missions are undertaken. Investigators also studied changes in the cross-sectional areas of discs in the lower back. The experiment was sponsored by Methodist Hospital and Baylor College of Medicine, Houston, TX.

Direct Measurement of the Initial Bone Response to Space Flight: The dynamic human skeleton continually makes and removes bone from the body. In space, reduced gravitational loads may induce the skeleton to discard calcium; bone loss begins shortly after reaching orbit. While seeking countermeasures, researchers may discover treatments for the debilitating disease osteoporosis. The experiment was sponsored by the University of California, San Francisco, CA.

Measurement of Energy Expenditure During Space Flight with the Doubly Labeled Water Method: During missions, crew members often lose weight. Like malnourishment, burning more calories than are ingested results in the breakdown of the body's protein reserves, which can lead to impaired performance and illness. The doubly labeled water method accurately measures energy output. Participants drink water with two nonradioactive isotopes that are shed by the body at different rates and by different paths. Energy expenditure were analyzed using urine and saliva specimens. To learn how the energy needs in space vary from requirements on Earth, researchers compared in-flight data with pre-flight and bedrest data. The experiment was sponsored by the University of Medicine and Dentistry of New Jersey, Stratford, NJ.

Extended Studies of Pulmonary Function in Weightlessness: Previous flight studies indicate gravity is not the only factor in perfusion/ventilation gas flow and blood flow differences between the top and bottom of the lung. These changes were measured before and during exercise to determine the mechanisms of ventilatory changes. The experiment was sponsored by the University of California/San Diego, La Jolla, CA.

Human Sleep, Circadian Rhythms and Performance in Space: This was the first simultaneous study of sleep, 24-hour circadian rhythms and task performance in microgravity. Periodically during the mission, crew members wore a beltpack connected to a temperature sensor and another to a sleep cap with electrodes that measure brain waves, eye movements and muscle tone while sleeping. Mood and performance tests were performed. Urine samples were collected to help track normal daily rhythms. The experiment was sponsored by the University of Pittsburgh, PA (Ground Study), Institute of Aerospace Medicine, Cologne, Germany.

Microgravity Effects on Standardized Cognitive Performance Measures using the Performance Assessment Workstation: Cognitive, or thinking, skills are critical to successfully performing many on-board tasks. This experiment identified the effects of fatigue versus microgravity on specific information processing skills. The goal was to maximize productivity and job satisfaction of astronauts on extended missions. Astronauts used the Performance Assessment Workstation laptop computer to gather performance data including the speed and accuracy of responses to rotated letters, math problems, letter sequences, etc. The experiment was sponsored by the U.S. Air Force, Armstrong Laboratory, Brooks Air Force Base, TX.

Torso Rotation Experiment: Space adaptation syndrome, a common symptom of adjusting to microgravity, produces motion sickness. Although symptoms disappear in a few days, this syndrome is uncomfortable and affects performance. The flight crew at times wore sensor packages that measured eye, head and torso movements during normal on-orbit activities early, midway and late into the flight. The experiment was sponsored by McGill University, Montreal, Quebec, Canada.

Canal and Otolith Interaction Studies: On Earth, we take balance for granted. Those with balance problems, as well as astronauts, benefit from neuroscience research. On orbit, the vestibular system in the inner ear becomes confused as to which way is up or down. Disrupting inner ear motion sensors leads to nausea and disorientation. The experiment studied head movement and eye coordination in microgravity four times during the mission. Crew members used special head gear with a screen that displays visual and motion targets; data was collected on how the head and eyes track these cues. Readaptation times after flight also were monitored. The experiment was sponsored by the NASA Johnson Space Center, Houston, TX.

Lignin Formation and the Effects of Microgravity: Trees form inferior "reaction" wood when they right themselves from a bend. Lumber and paper industries want to know how to control and prevent this. Biologists studied how pine seedlings respond on a cellular level to bending stress in microgravity to study the mechanism of this tree growth. The experiment was sponsored by Washington State University, Pullman, WA.

Development of the Fish Medaka in Microgravity: During embryonic development, a single cell divides into many cells, which become organs and function as a living system. Medaka fish embryos helped researchers determine gravity's role in normal development. This knowledge contributed to theories about development conditions for other vertebrates, such as humans. The fish embryos grew in a culture system called the Space Tissue Loss Module in the middeck. The experiment was sponsored by Columbia College of Physicians and Surgeons, New York, NY.

Richard Linnehan works out in the Life and Microgravity Spacelab Science module.

Aboard the middeck, Astronaut Charles Brady, a licensed amateur radio operator, talks to students on Earth.

Role of Corticosteroids in Bone Loss During Space Flight: Corticosteroid hormones are produced by the adrenal gland in response to stress. Excess corticosteroids may contribute to bone changes during space flight, as well as other stressful periods. To develop effective countermeasures, scientists need to determine how microgravity affects bone mass, levels of bone formation and resorption, and bone cell activity. The experiment was sponsored by University of Florida, Gainesville, FL.

Bubble, Drop and Particle Unit -- Fluid Physics Research: Fluid physics research in the Bubble, Drop and Particle Unit (BDPU) may lead to advances in materials processed on Earth. These investigations help uncover processes involving either gas bubbles, liquid drops or liquid layers. Products that benefit from this research include new high-strength metals, and temperature-resistant glasses and ceramics for building everything from better electric power plants to future spacecraft. The BDPU was developed by the European Space Agency.

Bubbles and Drops Interaction with Solidification Fronts: As molten crystal and glass begin to solidify, gas bubbles may form, causing imperfections in the final product. Also, ingredients of liquid metal mixtures may separate during melting or solidification, forming bubbles or droplets in the mixture. This investigation provided insight into better ways to prevent these flaws from occurring. The experiment was sponsored by University of Naples, Italy.

Powered Small Electronic Devices by Boiling under Microgravity: Investigated heat transfer during boiling, using small heaters of different shapes and sizes. Since boiling is a very efficient way to exchange heat, it is used in many energy conversion systems that benefit from research in this field. For example, boiling can be used to cool small, high-powered electronic devices, such as computer chips. The experiment was sponsored by the Technical University of Munich, Germany.

The Electrohydrodynamics of Liquid Bridges provided information about the stability of columns of a dielectric material (in this case, a liquid) that barely conducts electricity when placed in another liquid or in air and is subjected to an electric field. This research may find application in industrial processes where the control of a liquid column or spray is necessary, such as ink-jet printing and polymer fiber spinning. The experiment was sponsored by Princeton University, Princeton, NJ.

Nonlinear Surface Tension Driven Bubble Migration investigated the motion of bubbles immersed in a liquid in a container with hot and cold walls on opposite sides. The study of this phenomenon applies to controlling defects in many aspects of materials processing in space, such as the solidification of better and stronger metals, alloys, glasses, and ceramics. The experiment was sponsored by the Second University of Naples, Aversa, Italy.

Oscillatory Marangoni Instability: Many manufacturing processes depend on melting and resolidifying a material encapsulated by a liquid coating in order to make single crystals for use in electronics. Often, the individual liquid components will flow due to Marangoni convection -- fluid flows caused by surface tension. Understanding this process is important for manufacturing of this nature. The experiment was sponsored by the Free University of Brussels, Belgium.

Coupled Growth in Hyper-monotectics: Scientists are interested in a number of unique alloys that cannot be easily produced on Earth because the ingredients separate during processing. Controlling the internal structure of these materials during solidification could lead to alloys for engineering, chemical and electronic applications. The experiment was sponsored by the University of Alabama at Birmingham, AL.

Interactive Response of Advancing Phase Boundaries to Particles: Many composites, such as metal mixtures with particles in their crystal structures, offer unique properties such as strength and flexibility. Understanding the interaction between free-floating particles and the growing edge of a solidifying material helped verify theoretical models used to develop new materials and design better industrial processes. This experiment investigated the effects of solidification conditions on the spread of particles in a sample as it crystallizes. The experiment was sponsored by the Aachen Center for Solidification in Space, Germany.

Particle Engulfment and Pushing by Solidifying Interfaces: This experiment was designed to improve the understanding of the physics of liquid metals containing ceramic particles as they solidify. It also investigated aspects of processing metal mixtures in microgravity to improve such processing on Earth. The experiment was sponsored by the University of Alabama, Tuscaloosa, AL.

Advanced Protein Crystallization Facility (APCF): The first facility ever designed to use three methods of protein crystal growth. By examining the molecular structure of proteins, medical researchers gain insight into these basic building blocks of life. The APCF experiments could improve food production, as well as lead to innovative new drugs to combat disease.

Advanced Protein Crystallization Facility on the Life and Microgravity Sciences Mission: These experiments contributed to better understanding of crystal growth on Earth and to the ability to define that process in conventional laboratories, possibly accelerating important advances in biotechnology, medicine, agriculture and industry. It grew a variety of protein and virus crystals. The experiment was sponsored by University of California, Riverside, CA.

Crystallization of EGFR-EGF: The receptor for the epidermal growth factor is an important predictor for a series of human diseases. Knowledge of the three-dimensional shape of this molecule could open the possibility of tailoring appropriate drugs for the treatment of numerous types of tumors. The experiment was sponsored by the European Molecular Biology Laboratory, Hamburg, Germany.

Crystallization of Crustacyanin Subunits: Crustacyanin is a member of the lipocalin protein group, which binds to certain pigments found in many plants and animals. Knowledge of the structure of the lipocalins will enable scientists to engineer proteins that will bind more strongly to pigments with anti-cancer properties. The experiment was sponsored by the Imperial College, London, United Kingdom.

Crystallization in a Microgravity Environment on CcdB, a Protein Involved in the Control of Cell Death: Better understanding of the shape and behavior of the CcdB protein may lead to the design of new antibiotics and anti-tumor drugs. Specifically, crystal quality needs to be improved. On STS-78, researchers wanted to crystallize three specific samples that are large enough for data collection. The experiment was sponsored by the Free University of Brussels, Belgium.

Crystallization of Sulfolobus Solfataricus Alcohol Dehydrogenase: Alcohol dehydrogenase (ADH) is found in large amounts in the livers of mammals and plays an important part in several functions, including the breakdown of alcohol. Mammalian ADH is unsuitable at high temperatures. This limits its application to the making of organic compounds. ADH from certain bacteria that grow in high temperatures has greater stability, however, and is less affected by high temperatures. This substance is a good candidate for industrial applications. The experiment was sponsored by the University of Naples, Italy.

CREW BIOGRAPHIES

Commander: Terence T. "Tom" Henricks (Colonel, USAF). Henricks, 44, was born in Bryan, OH, but considers Woodville, OH, to be his hometown. He graduated from Woodmore High School in 1970, received a bachelor of science degree in civil engineering from the United States Air Force Academy in 1974, and a masters degree in public administration from Golden Gate University in 1982.

Henricks was selected by NASA in June 1985 and became an astronaut in July 1986. A veteran of four space flights, Henricks has logged more than 1,025 hours in space. He was the pilot on STS-44 in 1991, and STS-55 in 1993, and was the spacecraft commander on STS-70 in 1995, and STS-78.

Pilot: Kevin R. Kregel. Kregel, 39, was born in Amityville, NY. He graduated from Amityville Memorial High School, Amityville, NY in 1974, received a bachelor of science degree in astronautical engineering from the U.S. Air Force Academy in 1978 and a master's degree in public administration from Troy State University in 1988.

Kregel was selected by NASA in March 1992. He was the pilot on STS-70 in 1995, and STS-78. He has now logged more than 609 hours in space.

Mission Specialist: Richard M. Linnehan (DVM). Linnehan, 38, was born in Lowell, MA. He graduated from Pelham High School, Pelham, NH in 1975, received a bachelor of science degree in animal sciences with a minor in microbiology from the University of New Hampshire in 1980 and the degree of Doctor of Veterinary Medicine from the Ohio State University College of Veterinary Medicine in 1985.

Linnehan was selected by NASA in March 1992. He completed his one year of training to be qualified for assignment as a mission specialist on a space shuttle flight crew in 1993. With the completion of STS-78, Linnehan has logged more than 405 hours in space.

Payload Commander: Susan J. Helms (Lt. Col., USAF). Helms, 37, was born in Charlotte, NC, but considers Portland, OR, to be her hometown. She graduated from Parkrose Senior High School, Portland, OR, in 1976, received a bachelor of science degree in aeronautical engineering from the U.S. Air Force Academy in 1980 and a master of science degree in aeronautics/astronautics from Stanford University in 1985.

Helms was selected by NASA in January 1990 and became an astronaut in July 1991. She has flown as a mission specialist on three shuttle flights - STS-54 in January 1993, STS-64 in September 1994 and STS-78. In completing her three missions, Helms has logged a total of 811 hours in space.

Mission Specialist: Charles E. Brady, Jr. (Commander, USN). Brady, 44, was born in Pinehurst, NC, but considers Robbins, NC, to be his hometown. He graduated from North Moore High School, Robbins, NC, in 1969, was pre-med at University of North Carolina at Chapel Hill, 1969-1971 and received a doctorate in medicine from Duke University in 1975.

Brady was selected by NASA in March

In-flight crew photo. Clockwise from top center- Susan Helms, Jean-Jacques Favier, Robert Thirsk, Kevin Kregel, Charles Brady, Richard Linnehan, Tom Henricks.

STS-78 Quick Look

Launch Date: June 20, 1996
Time: 9:49 a.m. CDT
Site: KSC Pad 39B

Orbiter: *Columbia*
OV-102-20th flight
Orbit/In.: 153 naut. miles
39 degrees

Mission Duration: 16 days, 21 hrs,
48 mns.
Landing Date: July 7, 1996
Time: 7:37 a.m. CDT
Site: Kennedy Space Center

Crew: Tom Henricks, (CDR)
Kevin Kregel, (PLT)
Rick Linnehan, (MS1)
Susan Helms, (MS2, PL CDR)
Charles Brady, (MS3)
Jean-Jacques Favier, (PS1)
Robert Thirsk, (PS2)

Cargo Bay Payloads: LMS
EDO Pallet

In-Cabin Payloads: SAREX

1992 and qualified for selection as a mission specialist on future space shuttle flight crews in 1993. In May 1995 he was assigned as a mission specialist for the LMS mission. With the completion of STS-78, Brady has logged more than 405 hours in space.

Payload Specialist: Jean-Jacques Favier (Ph.D.). Favier, 47, was born in Kehl, Germany. He attended primary and secondary schools in Strasbourg, France, received an engineering degree from the National Polytechnical Institute of Grenoble in 1971 and a Ph.D. in engineering from the Mining School of Paris and a Ph.D. in metallurgy and physics from the University of Grenoble in 1977.

Favier has been a CNES payload specialist candidate since 1985. He was assigned as an alternate payload specialist on Mission STS-65, the second International Microgravity Laboratory mission that flew in July 1994. In May 1995 was assigned as a payload specialist for the STS-78 LMS mission

Payload Specialist: Robert (Bob) Brent Thirsk (M.D., P.Eng.). Thirsk, 42, was born in New Westminister, British Columbia. He attended primary and secondary schools in British Columbia, Alberta, and Manitoba, received a bachelor of science degree in mechanical engineering from the University of Calgary in 1976, a master of science degree in mechanical engineering from the Massachusetts Institute of Technology (MIT) in 1978 and a doctorate of medicine degree from McGill University in 1982.

Thirsk was one of the six Canadian astronauts selected in December 1983 and served as back up Payload Specialist to Marc Garneau for STS-41G in October 1984. In April 1995, Dr. Thirsk was selected to participate in the Life and Microgravity Spacelab mission.

The STS-78 mission links past with present through a crew patch influenced by Pacific Northwest Native American art. Central to the design is the Space Shuttle *Columbia* whose shape evokes the image of the eagle, an icon of power and prestige and the national symbol of the United States. The eagle's feathers, representing both peace and friendship, symbolize the spirit of international unity on STS-78. An orbit surrounding the mission number recalls the traditional NASA emblem.
The Life Sciences and Microgravity Spacelab (LMS) is housed in *Columbia's* payload bay and is depicted in a manner reminiscent of totem art. The pulsating Sun, a symbol of life, displays three crystals representing STS-78's three high temperature microgravity materials processing facilities. The constellation Delphinus recalls the dolphin, friend of sea explorers, each star representing one member of STS-78's international crew including the alternate payload specialists: Pedro Duque and Luca Urbani.
The colored thrust rings at the base of *Columbia* signify the five continents of Earth united in global cooperation for the advancement of all humankind.

Pic 1: 78304018-Payload Specialist Robert Thirsk performs a test on his arm using the Torque velocity Dynamometer. In this view, Thirsk is measuring changes in muscle forces of the biceps and triceps.

Pic 2: 78368022- Astronauts Susan Helms and Tom Henricks prepare a sample cartridge containing semiconductor crystals for Spacehab research.

Pic 3: 78305022-Richard Linnehan works out in the Life and Microgravity Spacelab Science Module.

Pic 4: 78429017-Aboard the middeck, Astronaut Charles Brady, a licensed amateur radio operator, talks to students on Earth.

Pic 5: 78397030-In-flight crew photo. Clockwise from top center- Susan Helms, Jean-Jacques Favier, Robert Thirsk, Kevin Kregel, Charles Brady, Richard Linnehan, Tom Henricks.